Nanoscale properties of GaN nanowires grown on Si substrates with an AlN interfacial layer

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It is well established that self-assembled GaN nanowires (NWs) on Si(111) substrates grow on a thin amorphous Si_xN_y layer, that forms either due to intentional nitridation of the Si surface, or the intense N-rich conditions used for NWs growth by plasma-assisted molecular beam epitaxy (PAMBE). This layer is closely related to NWs misorientation from the growth direction, resulting in a high degree of NWs coalescence and consequently, affects their overall structural, electronic and optical properties. Transmission electron microscopy (TEM) techniques were employed to determine the optimum substrate surface treatment of GaN NWs growth on bare Si with or without nitridation of the surface, and on top of an AlN interfacial layer (IL) of varying thickness.
High-Resolution TEM (HRTEM) observations have shown that formation of the amorphous Si_xN_y layer takes place inevitably when the Si was nitridated, intentionally or not, prior to NWs growth. However, the axial inclination of NWs was improved when the surface was intentionally nitridated, owing to the formation of a thicker Si_xN_y at the GaN/Si interface and the atomically flat Si surface. The amorphous Si_xN_y layer was not prevented even when a 0.2 nm AlN IL was foremost deposited (Fig. 1(a)). In contrast, when the thickness of the AlN IL exceeded 0.4 nm, either as-grown or annealed under active nitrogen, the Si_xN_y layer was suppressed, leading to GaN NWs with superior axial alignment and crystal quality (Fig. 1(b)). Moreover, GaN nanoislands (NIs) appeared along with GaN NWs in all cases, which evolved into a compact faceted GaN layer including sparse GaN NWs with increasing thickness of the AlN IL.
It appears that in the initial stages of IL growth, AlN forms strained 3D islands that act as nuclei for the spontaneous growth of GaN NWs. Subsequently, during annealing, the AlN IL transforms into a partially-relaxed compact 2D layer that favors the formation of GaN faceted domains along with the NWs, while in the case of a fully relaxed 20 nm thick AlN IL, a compact GaN layer is formed.

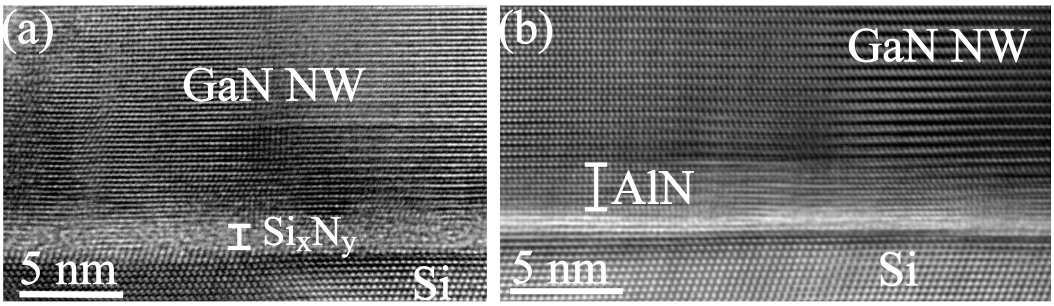

Figure 1: HRTEM images of the GaN/Si interfacial area, when (a) a 0.2 nm AlN IL was deposited prior to NWs growth, and (b) a 2 nm as-grown AlN IL was used.

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